S

Soil Stratigraphy

Vance T. Holliday[1], Rolfe D. Mandel[2] and Timothy Beach[3]
[1]School of Anthropology and Department of Geosciences, University of Arizona, Tucson, AZ, USA
[2]Department of Anthropology, University of Kansas, Lawrence, KS, USA
[3]Department of Geography and the Environment, The University of Texas at Austin, Austin, TX, USA

Introduction

Soil stratigraphy or *pedostratigraphy* is a way of grouping and correlating sediments and rocks based on soil-related, or pedogenic, criteria. This contrasts with *lithostratigraphy* (classification based on lithological characteristics such as color or grain size), chronostratigraphy (classification based on age of deposits or rocks), and *biostratigraphy* (classification based on biological characteristics such as pollen or vertebrate fauna) (see the entry on ► "Stratigraphy" in this volume). It has been defined as "the study of different soil associations formed in an area during past periods of varied soil-forming conditions" Catt (1990, 169). Here, the term *association* refers to a group of related soils that vary laterally due to changes in soil-forming factors. This is a more generic use of the term compared to the soil-mapping parlance of the USDA (see the entry on ► "Soil Survey" in this volume). The unique physical and chemical properties that distinguish soils from sediments make soils quite useful for stratigraphic subdivision and correlation. In particular, pedologic features, most notably soil horizons, are often the most visually prominent features in stratified deposits.

The recognition of soils and their differentiation from sediments in archaeological contexts (discussed below) is one of the most fundamentally significant aspects of geoarchaeological stratigraphy. Because soils indicate periods of stability or hiatuses in deposition (so that the soils have a chance to form), the identification of soils or the lack thereof in a stratigraphic sequence provides information on the number of depositional episodes and intervals of stability. The identification of specific soil horizons also provides clues to the degree and duration of soil development (see the entry on ► "Soils" in this volume), the nature of the soil-forming environment, and the kinds of soil-forming processes that may impact the archaeological record (see entry on ► "Site Formation Processes" in this volume).

Soil stratigraphic units have been defined in several ways. They are formally referred to as *pedostratigraphic units* in the North American Stratigraphic Code (NACSN 2005, 1576–1578). A pedostratigraphic unit is a "buried, traceable, three-dimensional body of rock [or sediment] that consists of one or more differentiated pedologic horizons" developed in and overlain by "one or more formally defined lithostratigraphic or allostratigraphic units" (NACSN 2005, 1576–1577).

There are several disadvantages to the NACSN definition, particularly in geoarchaeological contexts. The requirement that the soils be buried is illogical and, in any case, impractical in many field situations. The processes that govern whether or not a soil is buried can be variable and highly localized, particularly in Holocene deposits such as dunes and floodplains where buried soils may be exposed by erosion. The NACSN definition can result in a situation where a clearly traceable soil that is locally buried or exposed is a pedostratigraphic unit in some places but not in others. Likewise, the requirement that pedostratigraphic units be developed in and overlain by formally defined stratigraphic units is impractical and unrealistic because formally defined Holocene strata are rare, and formally defined Quaternary units are only locally common. Finally, the NACSN does not indicate how far a buried soil must be traceable for it to be classified as a pedostratigraphic unit. For example, a buried soil that is developed in Holocene alluvium may be traceable in a particular drainage basin or even a small part of a basin, but it may not occur beyond this area. Hence, there may be

© Springer Nature Switzerland AG 2023
A. S. Gilbert et al. (eds.), *Encyclopedia of Geoarchaeology*, Encyclopedia of Earth Sciences Series,
https://doi.org/10.1007/978-3-030-44600-0_177-1

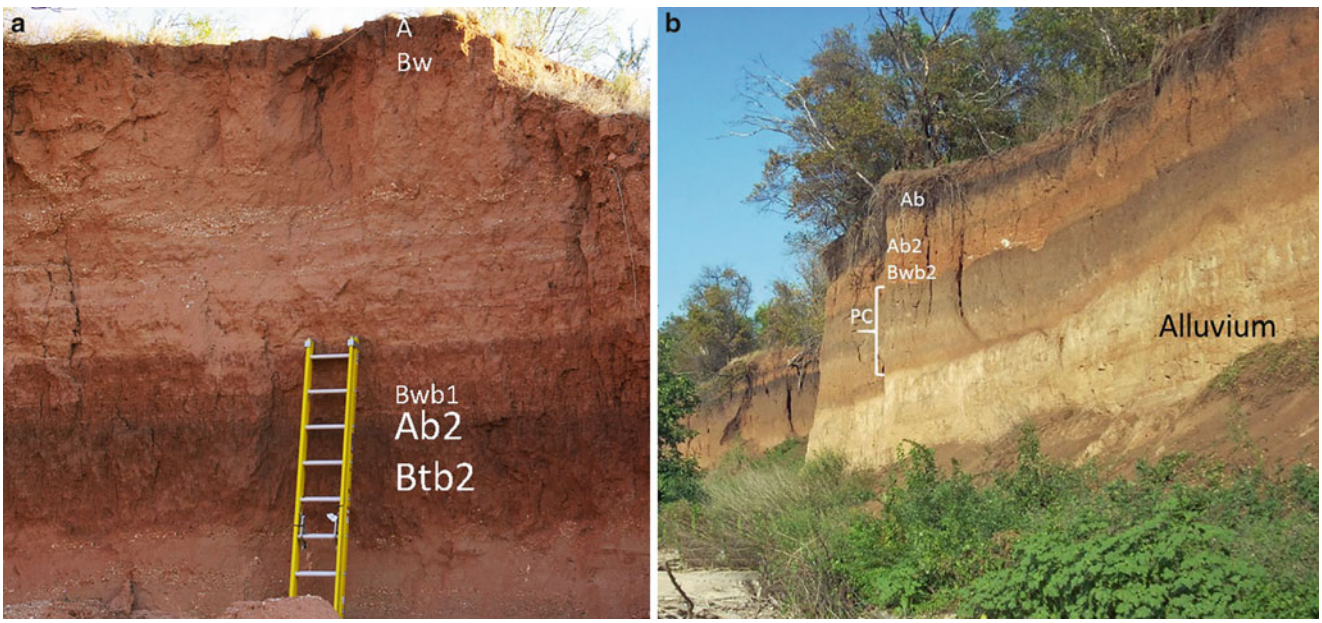
uncertainty as to whether that soil can be classified as a pedostratigraphic unit.

Several terms have been proposed as the "fundamental unit" of pedostratigraphic classification (i.e., a term equivalent to *formation* as the fundamental unit of lithostratigraphic classification). In the North American Stratigraphic Code, *Geosol* was adopted as the fundamental unit. "Geosol" was chosen over "soil" apparently because of the many different definitions and connotations of "soil," but there is rarely any confusion over the meaning of "soil" among geoarchaeologists, geomorphologists, or Quaternary stratigraphers. Other terms with a connotation more or less similar to Geosol include *groundsurface* (Butler 1959), *pedolith* (Crook and Coventry 1967), *pedo-morpholith* (van Dijk et al. 1968), and *pedoderm* (Brewer et al. 1970). Using "soil" to refer to pedostratigraphic units seems the most straightforward approach, however. Ultimately, field investigators should choose the terminology that best suits their situation.

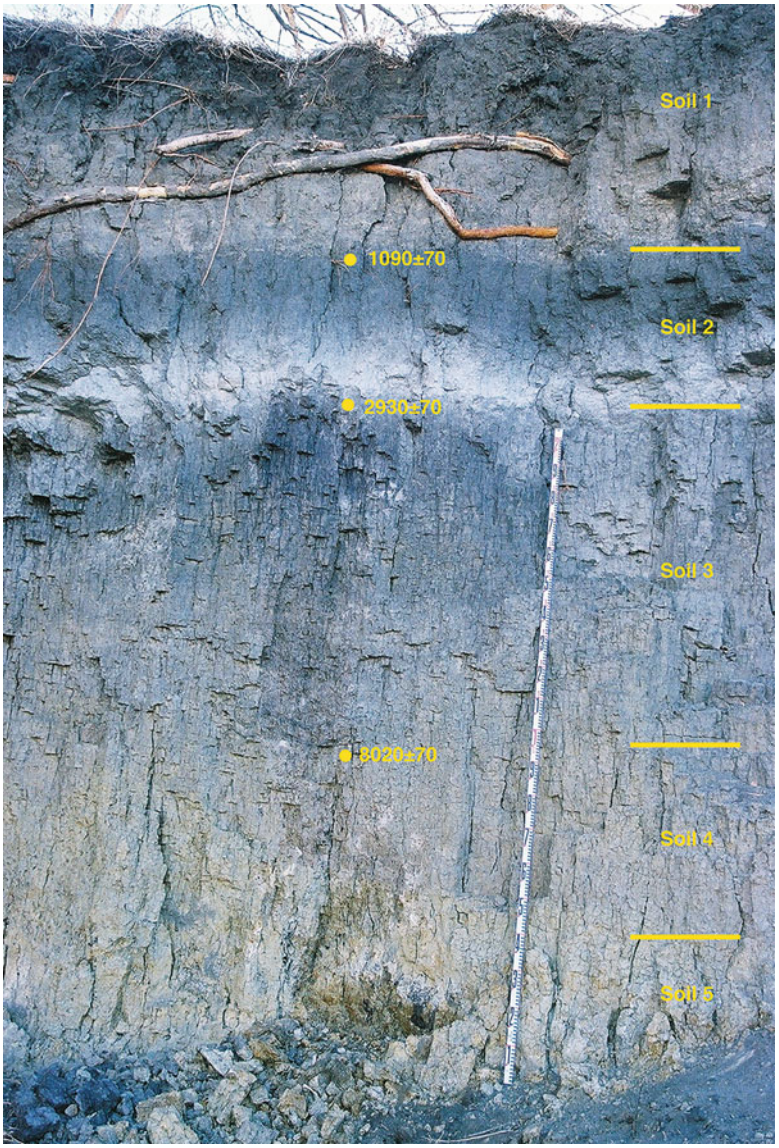
A wide variety of sometimes confusing terminology has been proposed and used to describe the many possible stratigraphic relationships between and within buried soils and soil stratigraphic units. Most of the terms are seldom used, largely because they lack utility in illuminating depositional or landscape history. A review of these terms, however, is a good way to examine them systematically and explain possible stratigraphic relationships among buried soils.

A classical, vertically stacked sequence of buried soils common in many alluvial, colluvial, eolian, and glacial landscapes is a multistory sequence (Fig. 1a and b). Closely spaced, multiple buried soils are described by a number of stratigraphic terms. If pedogenic processes from an upper soil extend down into or "overlap" with a lower soil, the process is referred to as soil *welding* and produces a set of *welded soils* (Fig. 2) (Ruhe and Olson 1980). Welded soils are also referred to as *polypedomorphic soils* (Bos and Sevink 1975; Duchaufour 1982, 144), *composite soils* (Morrison 1967, 25, Morrison 1978, 83–84), and *complex soils* (Bos and Sevink 1975, 224–225). Soil welding is an important process of post-burial alteration of soils. In Europe, the term *pedocomplex* is often used to describe closely spaced sets of either welded or unwelded soils and also to describe overthickened or cumulic soils (Fig. 1b) (see below). In the field, workers will find any combination of welded soils, unwelded soils, pedocomplexes of both, subdivided polygenetic soils, deeply buried soils, and shallowly buried soils. Lateral variation in rates of sedimentation, for example, on a floodplain, can also produce facies between multistory soils, welded soils, and cumulic soils (Fig. 3).

A significant aspect of soil stratigraphic units is that, like surface soils, they vary as the factors that influenced their



Soil Stratigraphy, Fig. 1 Examples of different expressions of buried soils. (**a**) A typical multistory sequence from the headwaters of the Brazos River system on the Rolling Plains of Northwest Texas. Below the surface soil and above the first buried soil (Bwb1) is sandy and gravelly alluvium, and immediately above the buried soil, finer muddy alluvium. The soil structure in the A-Btb2 is very well expressed due to high clay content. More sandy and gravelly alluvium is apparent at the base of the section (photo by Vance T. Holliday). (**b**) Buried soils exposed along the Dnieper River, Ukraine. The Ab-Ab2-Bwb2 multistory sequence and the pedocomplex (PC) formed in late Pleistocene loess, but they are separated by a distinct erosional unconformity. The PC includes both cumulic and welded soils. The PC rests unconformably on bedded alluvium. (Photo by Vance T. Holliday)

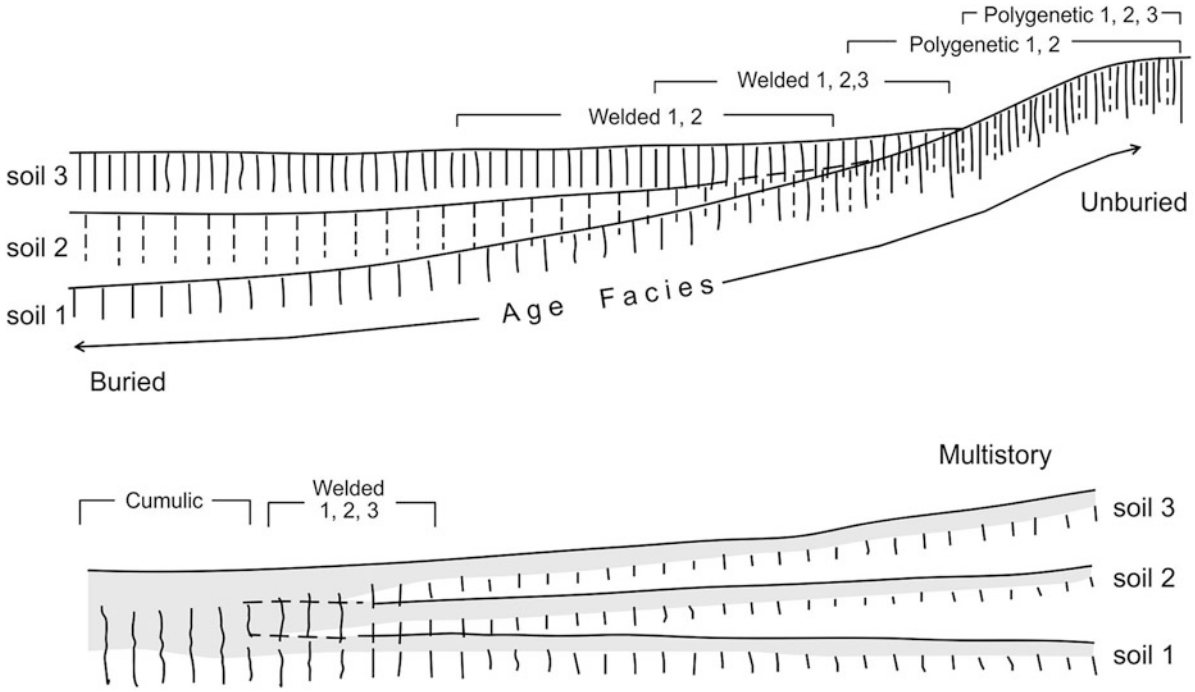


Soil Stratigraphy, Fig. 2 Soil stratigraphy of an alluvial fan exposed in a stream bank along Oak Creek in Southeastern Nebraska. Soil 2 has a well-expressed A-E-Bt profile, with the Bt horizon welded to the A horizon of Soil 3 just beneath. In the upper 35 cm of Soil 3, soil welding accounts for the prominent prismatic structure and clay films typical of a Bt horizon, but a dark gray matrix color typical of an A horizon. (From Mandel 2013a, Fig. 94)

development (parent material, topography, vegetation, biota, and time) varied. This is a very useful concept in soil stratigraphy because buried soils, like surface soils, can vary laterally. For example, a buried soil that formed in several different parent materials will exhibit different lithological facies. A soil stratigraphic unit that is buried in some places but not in others will exhibit facies variations due to the differences in the age of the soil, i.e., in the amount of time the soil had to form, and possibly due to environmental variations. Soil facies are lateral variations in soils due to variations in one or more of the soil-forming factors (Morrison 1967, 13, 15; 1978, 86–87).

Of particular significance when using soils as age indicators is that buried soils, just like lithostratigraphic units and contemporary surface soils, are diachronic or time transgressive. The age of the upper boundary of the pedostratigraphic unit can vary as the age of the paleo-land surface associated with the soil varied. Rapid burial over a large area can also produce a buried soil with an isochronous upper boundary (at least within the limits of most dating methods), however.

Variation in a buried soil or soil stratigraphic unit due to variation in the topography and drainage conditions during soil genesis produces a *paleocatena*. Most typically, a paleocatena is simply a buried catena (see entry on ▶ "Soils" in this volume). The concept of a buried catena or paleocatena is important because this is a unique aspect of soils relative to other kinds of stratigraphic units and is a key to the recognition of buried soils. Soil stratigraphic units should and do vary just as modern soils at the surface vary today.

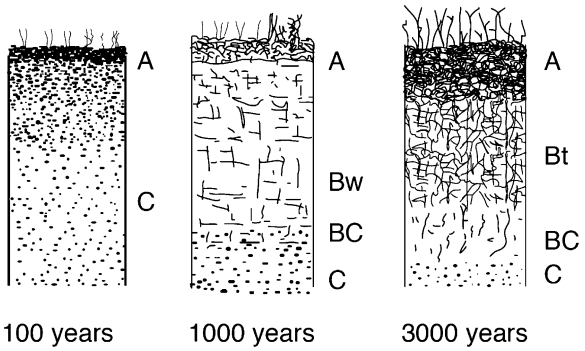


Soil Stratigraphy, Fig. 3 Schematic diagrams illustrating the soil stratigraphic and facies relationships of buried, unburied, and cumulic soils and associated terminology. In the *upper* diagram, duration of pedogenesis in the unburied, polygenetic soil is equal to the combined duration of pedogenesis for soils 1, 2, and 3, plus the time of sedimentation; modified from Holliday (2004, Fig. 5.3)

Soil Stratigraphy Versus Soil Horizonation

The many variables in local and regional soil-forming factors mean that the number and thickness of soil horizons in a soil stratigraphic unit and the position of the lower boundary of the soil can vary significantly. The individual soil horizons and the lower boundary of the soil, therefore, have no stratigraphic significance whatsoever other than to define the soil stratigraphic unit. The lower boundary can be, like the upper one, time transgressive or diachronic. It represents the lowermost significant alteration of the parent material by pedogenic processes.

Soil horizons are not geologic layers; horizons represent an alteration of the layers. The concept of soil horizonation and the specific spatial succession of soil horizons is a significant pedologic paradigm with important stratigraphic ramifications. Soil horizonation extends from the surface downward through the parent material, as a function of pedogenic processes, and thus individual soil horizons should not be understood as individual stratigraphic entities. Soil horizons are separated in space but are not necessarily separated in time, though some horizons may evolve sequentially after others form (e.g., an A-C profile evolving into an A-Bw-C soil and then into an A-Bt-C sequence) (Fig. 4). Moreover, soil horizons, particularly the A, can be thoroughly churned due to the effects of floral and faunal mixing and argilliturbation (see the entry on ► "Site Formation Processes" in this volume). For a comparison of soil horizonation and geologic layers, see ► "Lubbock Lake Site, Texas", Fig 2.



Soil Stratigraphy, Fig. 4 Diagrams showing the hypothetical development of a soil through time, keeping all other soil-forming factors constant. The setting is on the valley floor of a stream in the tallgrass prairie of Eastern Kansas, a region with a mean annual rainfall of about 82 cm

Buried Soils

Soil stratigraphy deals with buried soils, which is to say, it deals with buried landscapes. They are three-dimensional bodies, and because soils require some time to form, they can be considered four-dimensional entities. Waters (1992,

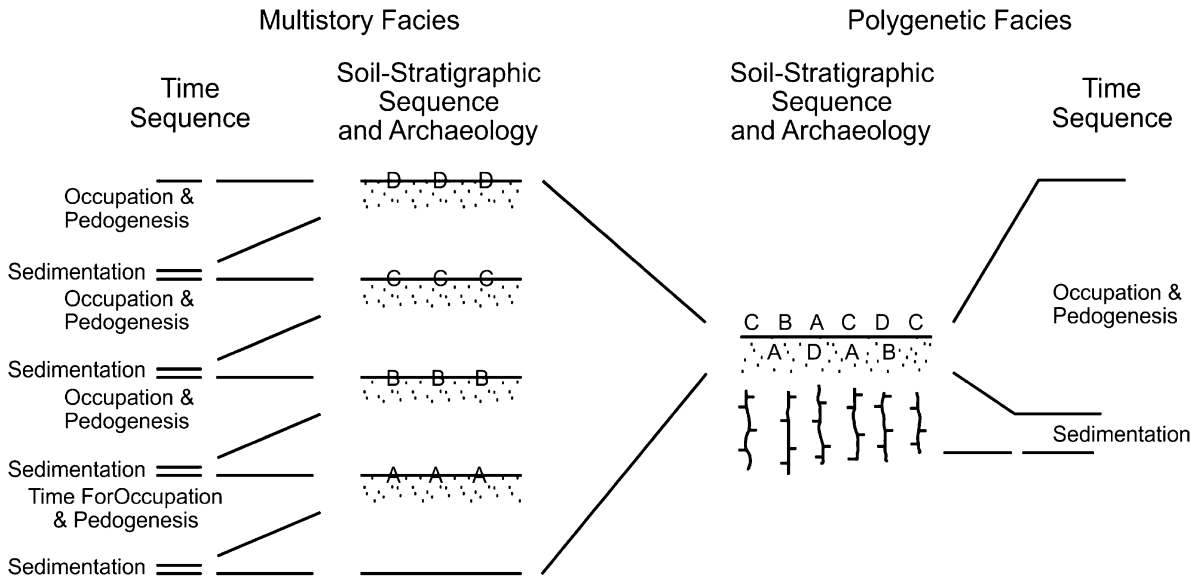
82–83) provides a good description of the evolution of strata, one particularly appropriate to the visualization of buried soils (see also Kraus and Brown 1988; Kraus 1999; Kraus and Aslan 1999):

> The nature and structure of a stratigraphic sequence in any environment is determined by the number, timing, areal extent, magnitude, and duration of individual periods of deposition, degradation, and stability.... Over a given interval of time, individual episodes of deposition, stability, and erosion may be of long duration, with changes occurring infrequently, or they may be of short duration and alternate frequently. Furthermore, these episodes may affect a large region or only a small area. Consequently, different. . .sequences of lithostratigraphic units, pedostratigraphic units, and erosional contacts are created.
>
> The total duration of deposition, degradation, and stability determines how much of the time continuum of a stratigraphic sequence is recorded by. . .depositional units (lithostratigraphic units) versus the combined time represented by. . .surfaces of erosion (erosional unconformities) and surfaces of stability (pedostratigraphic units). Episodes of landscape degradation [and/or] stability create gaps in any depositional sequence and thus leave an incomplete geologic record of lithostratigraphic units. The ratio of the total amount of time represented by nondepositional and erosional contacts between lithostratigraphic units produces a measure of the completeness of the stratigraphic sequence.... Generally this ratio is low because the contacts between and within lithostratigraphic units represent the passage of more time than the physical sediments themselves.... (Waters 1992, 82–83).

An important point raised in this quote is that soils represent gaps in the sedimentological record – i.e., periods of generally stable landscapes – because there was little or no deposition or erosion. More broadly, recognizing buried soils and establishing soil stratigraphic relationships are important for a wide array of geoarchaeological questions and interpretations. For example, a multistory sequence of weakly expressed buried soils is indicative of rapid sedimentation interrupted by relatively brief periods of stability and soil formation. Such settings could preserve discrete occupation surfaces (Fig. 5). On a floodplain, as described above and in Fig. 3, this geoarchaeological record could have facies of welded, cumulic, or unburied soils with a mixed or palimpsest archaeological record.

Recognition

Recognition of buried soils depends on (1) the degree of preservation of the soil (which in turn depends on the nature of the burial processes and post-depositional alterations) and (2) the experience of the investigator, including experience working with surface soils and with stratigraphic studies in the given field area. Fundamentally, buried soils can be recognized using the same characteristics used to recognize surface soils (Yaalon 1971a, 154, 157; Valentine and Dalrymple 1976, 209–213; Fenwick 1985, 5–11; Jenkins 1985; Catt 1986, 173–174; Catt 1990, 6–7; Birkeland 1999, 24–28). In



Soil Stratigraphy, Fig. 5 Diagram illustrating the impact of varying rates of deposition on the archaeological record. On the *left* side, frequent episodes of flooding and sedimentation produce multistory facies with multiple, weakly expressed soils (indicated by stippling) containing relatively discrete occupation zones (A, B, C, and D), whereas on the *right* side prolonged stability results in a few polygenetic soils or a single one with a palimpsest or mixing of different occupation debris; modified from Holliday (2004, Fig. 7.2)

the field, these characteristics include the absence of geologic bedding, recognizable soil horizons, horizons in a typical vertical sequence, typical soil horizon boundaries (sharper upper boundary and more gradual lower boundary), and the formation of stone lines in some environments. Bettis (1992, 129) provides a useful summary of criteria for differentiating soil A horizons from organic-rich alluvium, criteria also applicable to distinguishing other kinds of soil horizons: (1) a gradual or clear lower boundary for A horizons as opposed to an abrupt lower boundary in geologic deposits; (2) absence of bedding in A horizons and its presence in geologic deposits; and (3) the presence of granular or crumb soil structure in A horizons and its absence or weaker development in geologic deposits.

One significant problem in the identification of buried soils is that a number of sedimentary, hydrogeologic, and pedogenic processes can produce zones that look like buried soils (Pyddoke 1961, 37–39; Tamplin 1969, 153–154; Brewer 1972, 332; Rutter 1978; Catt 1986, 173; Thorson 1990, 402–403, 405–406; Ito et al. 1991; Tandon and Kumar 1999, 131–135; Mandel and Bettis 2001, 175–180). These processes and deposits include: (1) deposition of organic-rich sediment in lacustrine, palustrine, or alluvial settings (which can be confused with A horizons); (2) deposition of red, reddish brown, or brown sediment (which can be confused with Bw or Bt horizons); (3) deposition of clay-rich sediment (which can be confused with Bt horizons); (4) deposition of gray sediment (which can be confused with a redoximorphic horizon); (5) deposition of volcanic ash (which can be confused with Bk or in particular E horizons); (6) illuviation of humus in a Bh or Bhs horizon below a leached, sandy E horizon (which can be confused with an A horizon buried below unweathered sand); and (7) deposition of calcium carbonate, soluble salts, or iron oxides in lacustrine, palustrine, alluvial, spring, or groundwater settings (which can be confused with Bk, K, By, Bz, or Bs horizons). Post-burial processes such as black, manganese staining and nodule formation also can produce zones that may be mistaken for soil horizons.

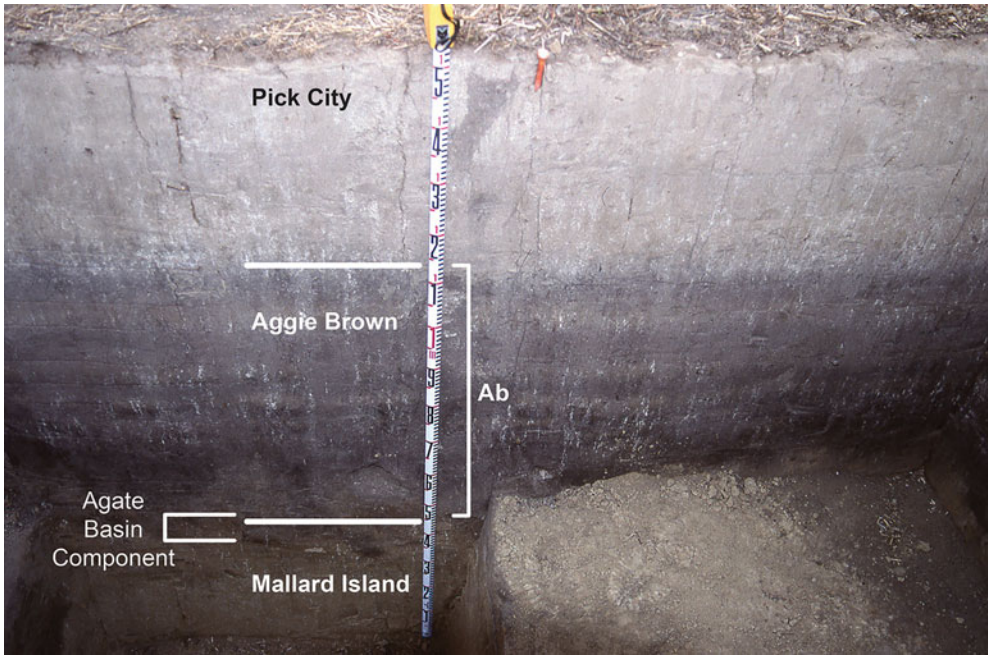
A particularly important characteristic that can be crucial in identifying a buried soil is predictable, lateral variability in morphology ("constancy of relationships" of Brewer 1972, 333) due to topographic variability (i.e., it is part of a *paleocatena*) and due to parent material variability, both discussed above. The topographic and catenary variability of soils is a unique characteristic particularly important in the identification of buried soils, one not likely mimicked by other geological phenomena (Brewer 1972; Valentine and Dalrymple 1975, 1976; Finkl 1980; Catt 1986, 168–169). This characteristic of soils allows them to be traced in three dimensions over varying paleotopography. Individual layers of sediment, in contrast, will be confined to particular depositional environments and will thin to nothing as one moves away from that environment (Mandel and Bettis 2001, 180).

Burial Processes

The recognition and interpretation of buried soils can be complicated by several processes that take place before, during, or after burial. As a landscape is buried, some or all of the following processes can operate, depending on landscape position and the nature of the burial process(es).

1. Rapid burial that leaves a complete soil profile preserved under younger sediment. Processes of rapid sedimentation alternating with periods of relative landscape stability and weathering produce multistory sequences of buried soils (Figs. 1a, 3, and 5).
2. Erosion prior to burial resulting in a truncated soil profile preserved under younger sediments.
3. Slow burial that allows pedogenesis to keep pace with sedimentation. The result is upbuilding (Johnson and Watson-Stegner 1987) or overthickening or cumulization of a soil (Buol et al. 1997, 91). Overthickening means that a particular horizon literally becomes thicker than average

Soil Stratigraphy, Fig. 6 A buried soil with an overthickened Ab horizon developed in late Holocene alluvium at the Alum Creek site (14EW171) in Central Kansas. The Ab horizon is 1.2 m thick and contains stratified middle ceramic cultural deposits. (Modified from Mandel and Bettis 2001, Fig. 7.3)

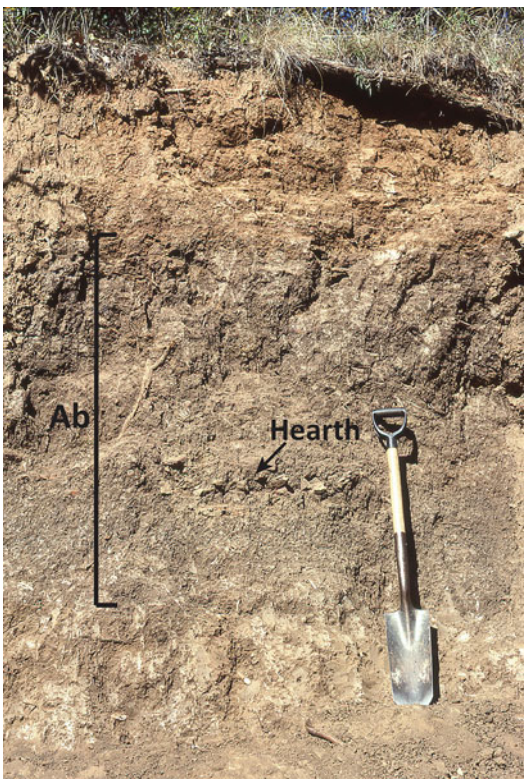


Soil Stratigraphy, Fig. 7 The cumulic Ab horizon of a buried paleosol developed in the Aggie Brown Member at the Beacon Island site, an Agate Basin (Paleoindian) bison kill in Northwestern North Dakota. The Ab horizon exhibits faint bedding typical of many cumulic soils. (Modified from Mandel et al. 2014, Fig. 8)

(relative to more typical horizons associated with similar soils in similar settings in the region) (Fig. 6). Overthickened soils are referred to as accretionary (Catt 1990, 6) or cumulative (Nikiforoff 1949, 227–228; Birkeland 1999, 165–167), and overthickened horizons are called cumulic in Soil Taxonomy (Soil Survey Staff 1999, 155). Soil Taxonomy (Soil Survey Staff 1999, 155) further distinguishes between cumulic and pachic horizons: cumulic horizons can exhibit evidence for stratification (Fig. 7), whereas a pachic horizon is overthickened with no evidence of stratification (Fig. 8). In general parlance, however, cumulic is usually applied to both situations.

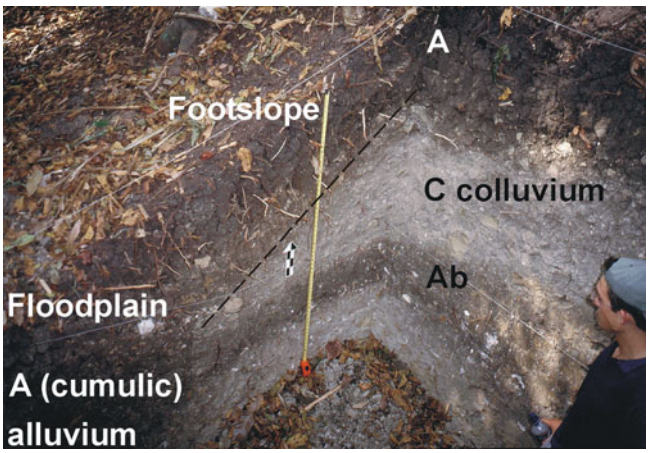
In describing the processes of overthickening, some investigators distinguish between the effects of slow rates of burial and moderate rates of burial (Follmer 1982, 120; Cremeens and Hart 1995, 23–24). The difference between an overthickened soil and several welded soils, therefore, is related to local rates of sedimentation. A set of welded soils and a single overthickened soil could be facies of one another (e.g., Kemp et al. 1997). This facies relationship could be at the scale of a floodplain or valley or at a regional scale. Geoarchaeologically, variation in rates of burial of soils and occupation debris will significantly affect where in a soil an archaeological horizon will occur.

Most typically, overthickening affects the A horizon and results from moderate rates of sediment accumulation and burial, where organic matter additions and bioturbation



Soil Stratigraphy, Fig. 8 A buried soil with a pachic Ab horizon developed in late Holocene alluvium in Fish Creek valley, North Central Texas (Mandel 1992a). There is no evidence of stratification in the overthickened Ab horizon. (Photo by Rolfe D. Mandel)

more or less keep pace with sedimentation. Overthickened A horizons are archaeologically significant because they can preserve stratigraphic relationships among artifacts, features, and living surfaces that are otherwise obscured or destroyed in the more typical A horizon. Some accretionary A horizons have weakly expressed stratification, which further aids in archaeological correlation and dating. In some places, the catena variation in soils produces a cumulic A horizon adjacent to an abruptly buried A horizon as in a floodplain abutting a footslope near Cancuen in Guatemala's Peten region (Fig. 9).

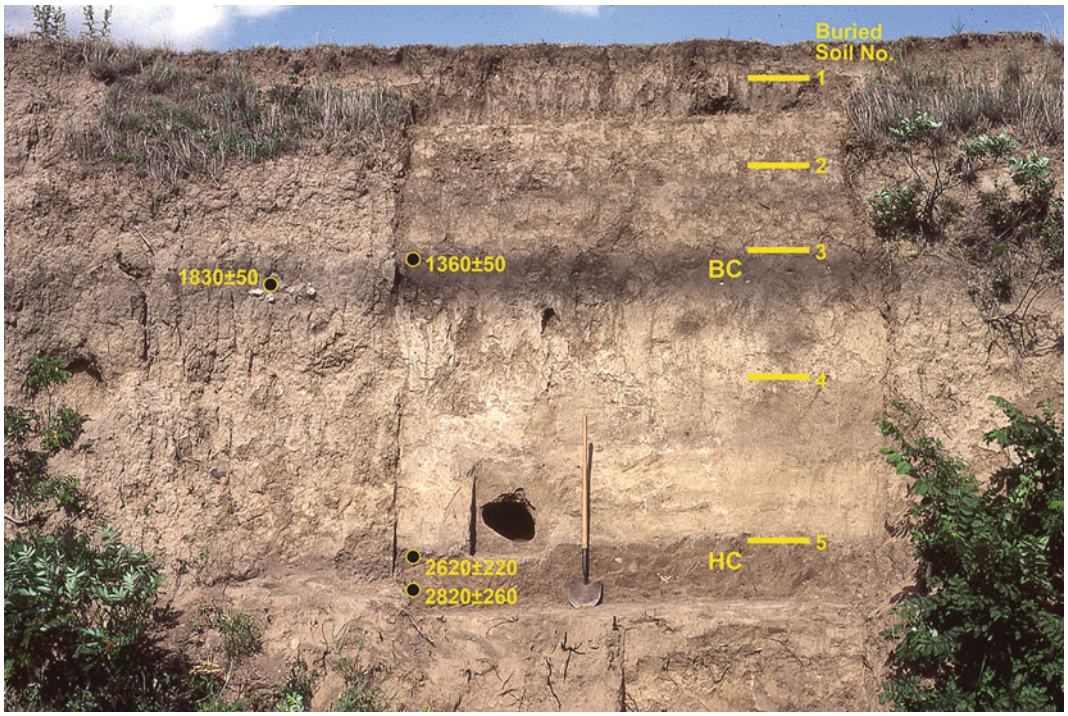


Soil Stratigraphy, Fig. 9 A cumulic soil developed in floodplain alluvium (*left*) is laterally inset against colluvium on a footslope. The buried soil developed in the colluvium dates to ca. 1200 BP (Beach et al. 2006)

Pedogenic features are clearly the primary clues to the presence of buried soils, but the morphologic and chemical characteristics typical of soils can undergo moderate to profound changes following burial. Yaalon (1971b) grouped soil horizons and features according to their relative persistence after burial. Generally speaking, the likelihood of preservation or persistence is related to the rate of development of the horizon. Soil features that form rapidly, such as the A horizon, tend to be the least persistent after burial, though many persist for at least 2000 years in the Maya Lowlands (Beach et al. 2015), whereas soil horizons that form more slowly, such as the Bt horizon, tend to be more persistent in buried soils.

The process of soil burial and then post-burial alterations can effectively obscure a buried soil. To summarize, the following questions can be posed as a means of identifying the partial or modified remains of a buried soil (modified from Catt 1990, 6–7):

1. Do the layers concerned contain fossil remains of plants (e.g., roots and charcoal), or artifacts, or geochemical



Soil Stratigraphy, Fig. 10 Soil stratigraphy of the T-1 alluvial fill exposed in the east bank of Buckner Creek at the Buckner Creek site (14HO306) in Southwestern Kansas. There are five buried soils, but only two – the Buckner Creek (BC) and Hackberry Creek (HC) paleosols – can be traced throughout Buckner Creek basin and other drainage systems in the region. The radiocarbon ages were determined on charcoal from cultural features; modified from Mandel (1992b, Fig. 2–13)

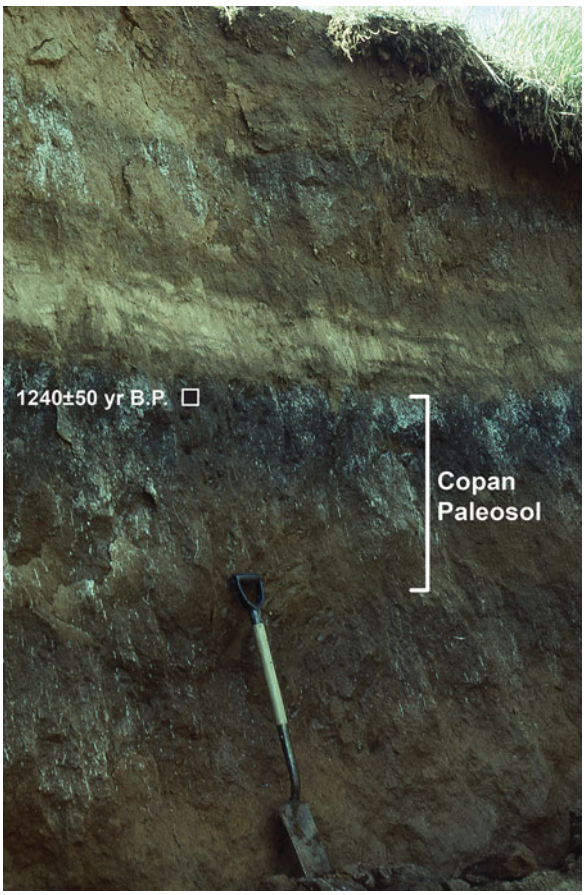
evidence (Beach et al. 2008) indicating the former presence of a land surface?
2. Do the layers display a vertical sequence of horizons that partly or wholly resembles what is typical of known types of modern surface soils?
3. If they are traced laterally, do the layers transgress bedding planes or other rock structures? If so, they are likely to be soil horizons, though in some soils, horizons develop parallel to bedding planes.
4. If they are traced laterally, do the transgressive layers change in character, not only in relation to changes in the underlying sediments or rock type but also in response to changes in the slope of the associated buried land surface? That is, do they form a paleocatena?

Applications of Soil Stratigraphy

Recognition of soil stratigraphy has many applications in archaeological investigations. At regional scales, buried soils can be used for stratigraphic correlation of occupation zones and archaeological sites (see entry on ▶ "Great Plains Geoarchaeology"). More locally, in archaeological surveys, buried soils may serve as stratigraphic "markers" used to target particular landform sediment assemblages for deep testing. Buried soils also may be used to determine the boundaries of a site, and where time-diagnostic artifacts and radiocarbon-datable materials are absent, they may be used to estimate the age of cultural deposits. At some archaeological sites, soil stratigraphy is crucial to understanding landscape evolution and site formation processes. Examples of the application of soil stratigraphy in archaeological investigations are presented below.

An archaeological survey of the Pawnee River watershed in Southwestern Kansas was preceded by an intensive, basin-wide study of alluvium and buried soils to determine their potential for buried cultural deposits. In the valleys of small streams (<fifth order), the Hackberry Creek Paleosol and the Buckner Creek Paleosol were identified beneath the lowest terrace (T-1) (Fig. 10) (Mandel 1988, 1992b, 1994). Radiocarbon ages indicate that the Hackberry Creek Paleosol formed ca. 2800–2000 years BP, and the Buckner Creek Paleosol developed around ca. 1700–1000 years BP. These two buried soils have thick, moderately expressed Ak-Bk profiles and occur in the valleys of all small streams in the Pawnee River basin. Other buried soils in the late Holocene alluvium comprising the T-1 fill have thin, weakly expressed A-C profiles reflecting only tens of years of pedogenesis (Mandel 1992b). Stratified late Archaic and Plains Woodland cultural deposits were recorded in the Hackberry Creek and Buckner Creek paleosols, respectively, whereas buried soils with A-C profiles were consistently sterile of archaeological materials (Mandel 1988, 1992b, 1994). This finding underscores the axiom that the longer the period over which a soil has developed, the higher its potential for containing cultural deposits at any given location. The Hackberry Creek and Buckner Creek paleosols were targeted for exploration during the subsequent archaeological survey of the Pawnee River basin (Timberlake 1988).

In situations where time-diagnostic artifacts and radiocarbon-datable materials are absent at a site, buried soils may be used as time-stratigraphic markers to estimate the age of cultural deposits. For example, in Eastern Oklahoma and Southeastern and South Central Kansas, a buried soil with a distinct overthickened (cumulic) A horizon is developed in late Holocene alluvium (Fig. 11). This soil, which is often referred to as the Copan paleosol (Hall 1977; Artz and Reid 1984; Artz 1985; Ferring 1986; Mandel 1993a, b) or Caddo paleosol (Hall 1980; Ferring 1982; Lintz and Hall 1983), developed between ca. 2000 and 1000 years ago. Because the buried soil is well dated and easy to recognize in late Holocene alluvial sections, it is a time-stratigraphic marker and has been used to estimate the age



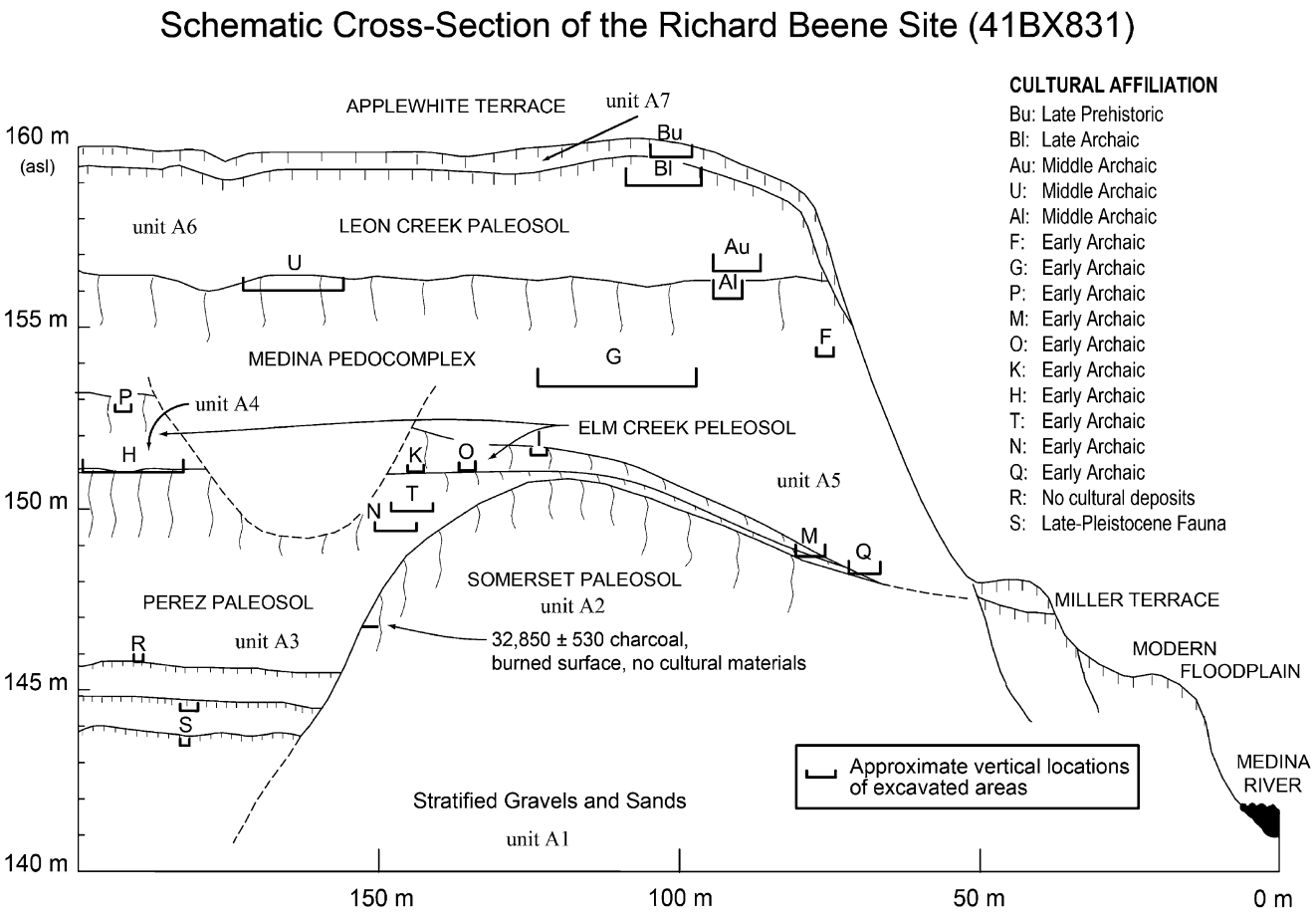
Soil Stratigraphy, Fig. 11 The Copan paleosol developed in the T-1 alluvial fill of Elm Creek in Barber County, South Central Kansas. The dark, organic-rich cumulic Ab horizon is 50 cm thick. The radiocarbon age was determined on soil organic matter. (Photo by Rolfe D. Mandel)

of cultural deposits contained in its horizons (e.g., Mandel 2013b).

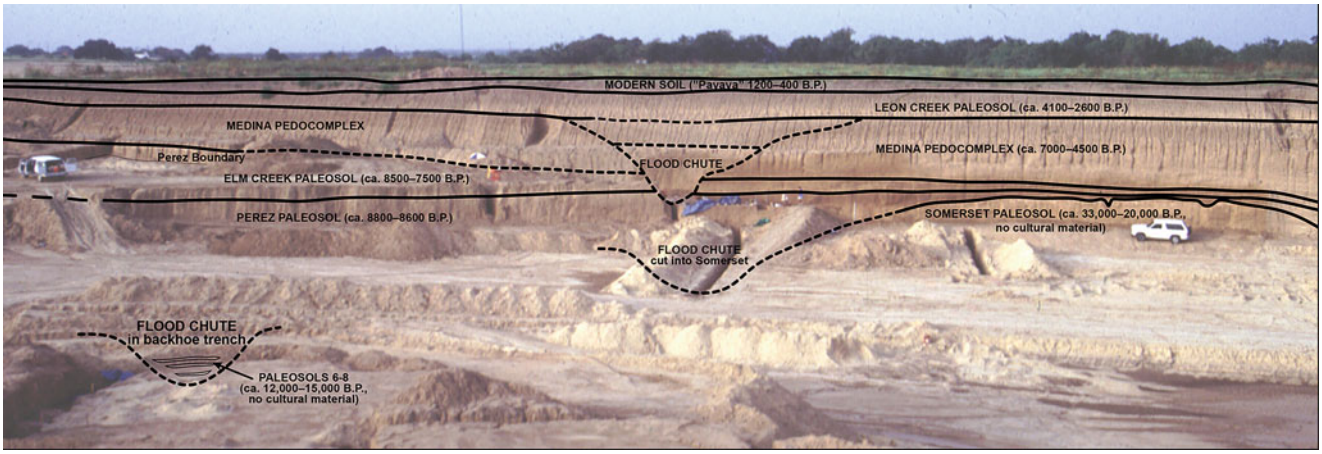
The boundaries of deeply buried archaeological sites may be difficult to determine by traditional excavation methods for logistical reasons. However, if the buried materials are on former stable surfaces (i.e., associated with distinct buried soils), soil stratigraphy, combined with deep testing, may be used to determine the spatial limits of cultural deposits. For example, investigation of deeply buried cultural deposits in alluvium at the Richard Beene site (41BX831) in the Medina River valley of South Central Texas identified seven major depositional units beneath the Applewhite terrace (Fig. 12) (Mandel et al. 2007). Soils are developed at the top of each unit, and archaeological materials are on and within the buried soils. The thickness of the fill terrace (>20 m), combined with complex stratigraphy that is a product of alluvial cutting and filling, presented a challenge to document the lateral extent of the cultural deposits. Mandel et al. (2007) defined the spatial limits of each buried cultural zone by using cores and a long, deep trench to trace the artifact-bearing buried soils, all designated as paleosols, and to identify their stratigraphic complexities (Fig. 13). These findings were critical to the development of excavation strategies that targeted some areas of the site for investigation while avoiding other areas (Thoms 2007).

In the Maya Lowlands, soil catena excavations at Blue Creek, Belize, uncovered a series of paleosols lumped together at the Eklu'um paleosol buried by colluvial, alluvial, hydrogeological, and anthropogenic processes from 2000–1000 years ago (Beach et al. 2008) (Fig. 14). The general driver was human slope alteration creating erosion along the slope but with aggradation in adjacent karst sinks, alluvial fans, footslopes, and the Rio Bravo floodplain. In the floodplain and some karst sinks, aggradation occurred by water table rise with gypsum precipitation and Maya adaptation with canalization and field raising, both obliterating and burying Vertisol, Mollisol, and Histosol paleosols.

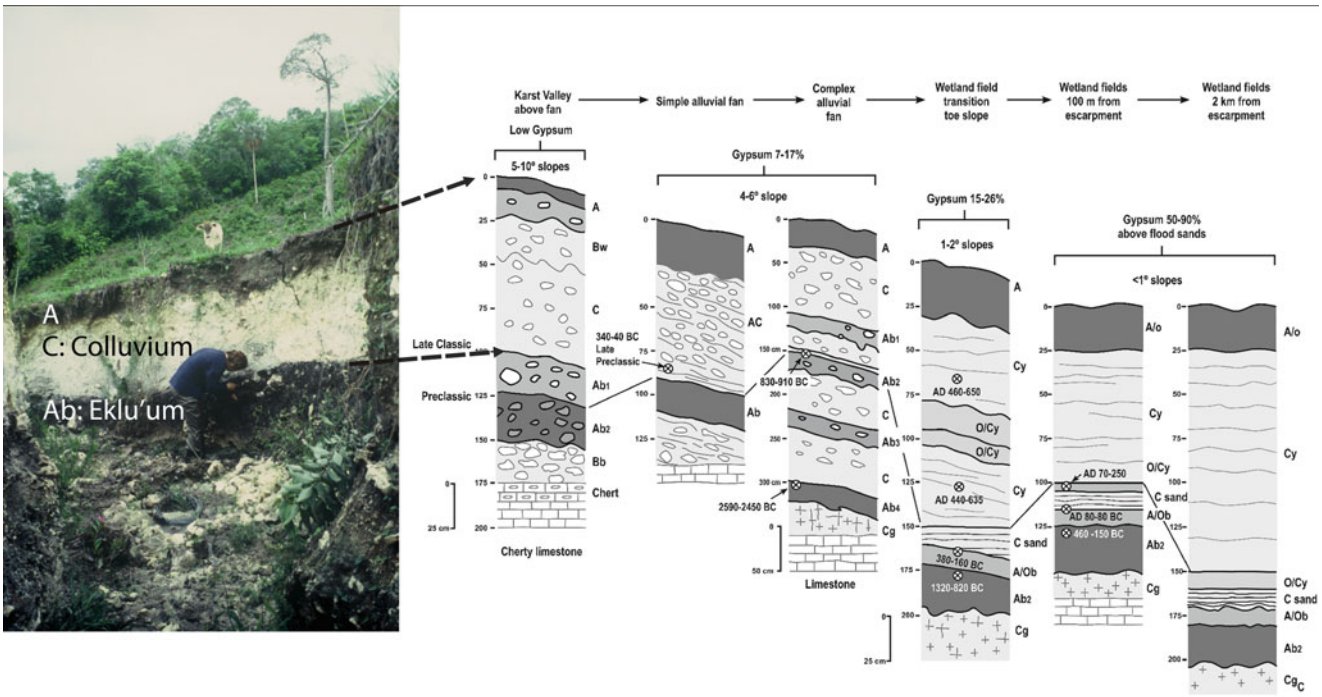
Soil stratigraphy has long been applied in the correlation of geologic deposits in Europe and Asia. This work also has been carried over into geoarchaeological correlations. In



Soil Stratigraphy, Fig. 12 Schematic cross-section of the south wall of the 20-m-deep spillway trench at the Richard Beene site showing stratigraphic units, soils, excavated areas, and archaeological stratigraphy. (Modified from Mandel et al. 2007, Fig. 3.3)


MODERN SOIL ("Pavaya" 1200–400 B.P.)
LEON CREEK PALEOSOL (ca. 4100–2600 B.P.)
MEDINA PEDOCOMPLEX
Perez Boundary
MEDINA PEDOCOMPLEX (ca. 7000–4500 B.P.)
FLOOD CHUTE
ELM CREEK PALEOSOL (ca. 8500–7500 B.P.)
PEREZ PALEOSOL (ca. 8800–8600 B.P.)
SOMERSET PALEOSOL (ca. 33,000–20,000 B.P., no cultural material)
FLOOD CHUTE cut into Somerset
FLOOD CHUTE in backhoe trench
PALEOSOLS 6-8 (ca. 12,000–15,000 B.P., no cultural material)

Soil Stratigraphy, Fig. 13 The central section of the south wall of the 20-m-deep spillway trench at the Richard Beene site showing the paleosols and associated radiocarbon ages determined on charcoal. (Modified from Thoms 2007, Fig. 4.6)



Soil Stratigraphy, Fig. 14 A catena near Blue Creek, Belize, showing the Preclassic Eklu'um paleosol predating 2000 BP buried by colluvium and alluvium with secondary accumulation of gypsum (Beach et al. 2008)

Tajikistan, buried soils in the loess record combined with paleomagnetic data have been used to correlate the Paleolithic archaeology and to provide age estimates for occupation zones at specific sites (see the ▶ "Loessic Paleolithic, Tajikistan" entry in this volume). More locally, soils in the alluvial stratigraphic record of terraces of the Don River in Southwestern Russia have been similarly applied to correlate and date the several dozen late Middle and Upper Paleolithic sites in the Kostenki-Borschevo area (see the ▶ "Kostenki, Russia" entry in this volume).

Cross-References

- ▶ Great Plains Geoarchaeology
- ▶ Kostenki, Russia
- ▶ Loessic Paleolithic, Tajikistan
- ▶ Lubbock Lake Site, Texas
- ▶ Site Formation Processes
- ▶ Soil Geomorphology
- ▶ Soil Survey
- ▶ Soils
- ▶ Stratigraphy

Bibliography

Artz JA (1985) A soil-geomorphic approach to locating buried late-archaic sites in Northeast Oklahoma. Am Archaeol 5:142–150

Artz JA, Reid KC (1984) Geoarchaeological investigations in Cotton Creek valley. In: Reid KC, Artz JA (eds) Hunters of the Forest edge: culture, time, and process in the little Caney Basin. Contributions in archaeology 14. Laboratory of Archaeology, University of Tulsa, Tulsa, pp 97–186

Beach T, Dunning N, Luzzadder-Beach S, Cook DE, Lohse J (2006) Ancient Maya impacts on soils and soil erosion in the central Maya lowlands. Catena 65(2):166–178

Beach T, Luzzadder-Beach S, Dunning N, Cook D (2008) Human and natural impacts on fluvial and karst depressions of the Maya lowlands. Geomorphology 101(1–2):308–331

Beach T, Luzzadder-Beach S, Cook D, Dunning N, Kennett DJ, Krause S, Terry R, Trein D, Valdez F (2015) Ancient Maya impacts on the Earth's surface: an early Anthropocene analog? Quat Sci Rev 124:1–30

Bettis EA III (1992) Soil morphologic properties and weathering zone characteristics as age indicators in Holocene alluvium in the upper Midwest. In: Holliday VT (ed) Soils in archaeology: landscape evolution and human occupation. Smithsonian Institution Press, Washington, DC, pp 119–144

Birkeland PW (1999) Soils and geomorphology, 3rd edn. Oxford University Press, New York

Bos RHG, Sevink J (1975) Introduction of gradational and pedomorphic features in descriptions of soils: a discussion of the soil horizon concept with special reference to paleosols. J Soil Sci 26(3):223–233

Brewer R (1972) Use of macro- and micromorphological data in soil stratigraphy to elucidate surficial geology and soil genesis. J Geol Soc Aust 19(3):331–344

Brewer R, Crook KAW, Speight JG (1970) Proposal for soil stratigraphic units in the Australian stratigraphic code. Report by the subcommittee for soil-stratigraphic nomenclature. J Geol Soc Aust 17(1):103–111

Buol SW, Hole FD, McCracken RJ, Southard RJ (1997) Soil genesis and classification, 4th edn. Iowa State University Press, Ames

Butler BE (1959) Periodic phenomena in landscapes as a basis for soil studies. CSIRO soil publication 14. Commonwealth Scientific and Industrial Research Organization, Melbourne

Catt JA (1986) Soils and quaternary geology: a handbook for field scientists. Clarendon, Oxford

Catt JA (1990) Paleopedology manual. Quat Int 6:1–95

Cremeens DL, Hart JP (1995) On chronostratigraphy, pedostratigraphy, and archaeological context. In: Collins ME, Carter BJ, Gladfelter BG, Southard RJ (eds) Pedological perspectives in archaeological research. SSSA special publication 44. Soil Science Society of America, Madison, pp 15–33

Crook KAW, Coventry RJ (1967) Climatically controlled quaternary sedimentation and soils in Ryans Creek valley, N.S.W. In: Congress of the Australian and New Zealand Association for the Advancement of Science, section C, abstracts T9-11

Duchaufour P (1982) Pedology, pedogenesis, and classification (trans: Paton TR). Allen and Unwin, Boston

Fenwick IM (1985) Paleosols: problems of recognition and interpretation. In: Boardman J (ed) Soils and quaternary landscape evolution. Wiley, Chichester, UK, pp 3–21

Ferring CR (ed) (1982) The late Holocene prehistory of Delaware canyon, Oklahoma. Contributions in archaeology 1. Institute of Applied Sciences, North Texas State University, Denton

Ferring CR (1986) Rate of fluvial sedimentation: implications for archaeological variability. Geoarchaeology 1(3):259–274

Finkl CW Jr (1980) Stratigraphic principles and practices as related to soil mantles. Catena 7(2–3):169–194

Follmer LR (1982) The geomorphology of the Sangamon surfaces: its spatial and temporal attributes. In: Thorn CE (ed) Space and time in geomorphology. Binghamton symposia in geomorphology 12. Allen and Unwin, London, pp 117–146

Hall SA (1977) Geology and palynology of archaeological sites and associated sediments. In: Henry DO (ed) The prehistory of the Little Caney River, 1976 season. Contributions in archaeology 1. Laboratory of Archaeology, University of Tulsa, Tulsa, pp 13–41

Hall SA (1980) Paleoenvironmental synthesis of Hominy Creek valley: pollen and land snail evidence. In: Henry DO (ed) The prehistory and Paleoenvironment of Hominy Creek valley, 1978 field season. Contributions in archaeology 6. Laboratory of Archaeology, University of Tulsa, Tulsa, pp 44–55

Holliday VT (2004) Soils in archaeological research. Oxford University Press, New York

Ito T, Shoji S, Shirato Y, Ono E (1991) Differentiation of a spodic horizon from a buried a horizon. Soil Sci Soc Am J 55(2):438–442

Jenkins D (1985) Chemical and mineralogical composition in the identification of paleosols. In: Boardman J (ed) Soils and quaternary landscape evolution. Wiley, Chichester, UK, pp 23–43

Johnson DL, Watson-Stegner D (1987) Evolution model of pedogenesis. Soil Sci 143(5):349–366

Kemp RA, Derbyshire E, Meng X-M (1997) Micromorphological variation of the S1 paleosol across Northwest China. Catena 31(1–2):77–90

Kraus MJ (1999) Paleosols in clastic sedimentary rocks: their geologic applications. Earth Sci Rev 47(1–2):41–70

Kraus MJ, Aslan A (1999) Palaeosol sequences in floodplain environments: a hierarchical approach. In: Thiry M, Simon-Coinçon R (eds) Palaeoweathering, palaeosurfaces and related continental deposits. International Association of Sedimentologists, special publication 27. Blackwell, Oxford, pp 303–321

Kraus MJ, Brown TM (1988) Pedofacies analysis; a new approach to reconstructing ancient fluvial sequences. In: Reinhardt J, Sigleo WR (eds) Paleosols and weathering through geologic time: principles and applications. GSA special paper 216. Geological Society of America, Boulder, pp 143–152

Lintz C, Hall SP (1983) The geomorphology and archaeology of Carnegie Canyon, Fort Cobb laterals watershed, Caddo County, Oklahoma. Oklahoma Conservation Commission, Oklahoma City

Mandel RD (1988) Geomorphology of the Pawnee River valley. In: Timberlake RD (ed) Phase II archaeological and geomorphological survey of the proposed Pawnee River watershed, covering subwatersheds 3 through 7, Ness, Fort, Lane, and Finney counties, Southwest Kansas. Kansas Historical Society, Topeka, pp 68–115

Mandel RD (1992a) Geomorphology of the upper Brazos River valley, North-Central Texas. In: Saunders JW, Mueller-Wille CS, Carlson DL (eds) An Archeological survey of the proposed South Bend reservoir area, Young, Stevens, and Throckmorton counties, Texas. Archeological surveys 6. Archaeological Research Laboratory, Texas A&M University, College Station, pp 53–84

Mandel RD (1992b) Soils and Holocene landscape evolution in central and southwestern Kansas: implications for archaeological research. In: Holliday VT (ed) Soils in archaeology: landscape evolution and human occupation. Smithsonian Institution Press, Washington, DC, pp 41–117

Mandel RD (1993a) Geomorphology. In: Weston T (ed) Phase II cultural resource survey of high potential areas within the Southeast Kansas highway corridor. Contract Archeology publication 10. Kansas State Historical Society, Topeka, pp 44–121

Mandel RD (1993b) Geomorphology. In: Hawley MF (ed) Cultural resource investigations for the U.S. highway 166 corridor. Contract Archeology publication 11. Kansas State Historical Society, Topeka, pp 24–75

Mandel RD (1994) Holocene landscape evolution in the Pawnee River valley, Southwestern Kansas. Kansas geological survey bulletin 236.

Kansas Geological Survey/Kansas State Historical Society, Lawrence/Topeka
Mandel RD (2013a) Geomorphological investigation. In: Palmer L, Buhta AA, Kruse JM, Mandel RD (eds) An Archeological and geomorphological survey of select lands along Oak Creek and Salt Creek in the vicinity of Lincoln, Lancaster County, Nebraska. Archeological contract series 260. Archeology Laboratory, Augustana College, Sioux Falls, pp 90–128
Mandel RD (2013b) Geoarchaeology and paleoenvironmental context of the Eastep site (14MY388), Southeast Kansas. The Kansas Anthropologist 33:159–174
Mandel RD, Bettis EA III (2001) Use and analysis of soils by archaeologists and geoscientists: a north American perspective. In: Goldberg P, Holliday VT, Ferring CR (eds) Earth sciences and archaeology. Kluwer Academic/Plenum Publishers, New York, pp 173–204
Mandel RD, Jacob JS, Nordt LC (2007) Geoarchaeology of the Richard Beene site. In: Thoms AV, Mandel RD (eds) Archaeological and Paleoecological investigations at the Richard Beene site (41BX831), south Central Texas. Reports of investigations no 8. Center for Ecological Archaeology, Texas A&M University, College Station, pp 27–60
Mandel RD, Murphy LR, Mitchell MD (2014) Geoarchaeology and paleoenvironmental context of the Beacon Island site, an Agate Basin (Paleoindian) bison kill in northwestern North Dakota, USA. Quat Int 342:91–113
Morrison RB (1967) Principles of quaternary soil stratigraphy. In: Morrison RB, Wright HE Jr (eds) Quaternary soils. University of Nevada, Desert Research Institute, Center for Water Resources Research, Reno, pp 1–69
Morrison RB (1978) Quaternary soil stratigraphy – concepts, methods, and problems. In: Mahaney WC (ed) Quaternary soils. Geo Abstracts, Norwich, UK, pp 77–108
NACSN (North American Commission on Stratigraphic Nomenclature) (2005) North American stratigraphic code. Am Assoc Pet Geol Bull 89(11):1547–1591
Nikiforoff CC (1949) Weathering and soil evolution. Soil Sci 67(3):219–230
Pyddoke E (1961) Stratification for the archaeologist. Phoenix House, London
Ruhe RV, Olson CG (1980) Soil welding. Soil Sci 130(3):132–139
Rutter NW (1978) Soils in archaeology. In: Rutherford GK, Savage PJ, Warkentin BP (eds) The geosciences in Canada, 1977: annual report and review of soil science. Geological survey of Canada paper 78-6. Geological Survey of Canada, Ottawa
Soil Survey Staff (1999) Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. USDA agriculture handbook 436, 2nd edn. US Department of Agriculture, Natural Resources Conservation Service, Washington, DC
Tamplin MJ (1969) The application of pedology to archaeological research. In: Pawluk S (ed) Pedology and quaternary research. The University of Alberta Printing Department, Edmonton, pp 153–161
Tandon SK, Kumar S (1999) Semi-arid/arid zone calcretes: a review. In: Singhvi AK, Derbyshire E (eds) Paleoenvironmental reconstruction in arid lands. A.A. Balkema, Rotterdam, pp 109–152
Thoms AV (2007) Excavation areas and site-formation contexts. In: Thoms AV, Mandel RD (eds) Archaeological and Paleoecological investigations at the Richard Beene site (41BX831), south Central Texas. Reports of investigations no 8. Center for Ecological Archaeology, Texas A&M University, College Station, pp 61–86
Thorson RM (1990) Geologic contexts of archaeological sites in Beringia. In: Lasca NP, Donahue J (eds) Archaeological geology of North America. GSA centennial volume, special, vol 4. Geological Society of America, Boulder, pp 399–420
Timberlake RD (ed) (1988) Phase II archaeological and geomorphological survey of the proposed Pawnee River watershed, covering subwatersheds 3 through 7, ness, fort, lane, and Finney counties, Southwest Kansas. Kansas Historical Society, Topeka
Valentine KWG, Dalrymple JB (1975) The identification, lateral variation and chronology of two buried paleocatenas at Woodhall Spa and West Runton, England. Quat Res 4:551–590
Valentine KWG, Dalrymple JB (1976) Quaternary buried paleosols: a critical review. Quat Res 6(2):209–222
Van Dijk DC, Riddler AMH, Rowe RK (1968) Criteria and problems in groundsurface correlations with reference to a regional correlation in South-Eastern Australia. In: Transactions of the 9th international congress of soil science, Adelaide, vol 4. International Society of Soil Science and Angus & Robertson, Sydney, pp 131–138
Waters MR (1992) Principles of Geoarchaeology: a north American perspective. The University of Arizona Press, Tucson, AZ
Yaalon DH (1971a) Criteria for the recognition and classification of paleosols. In: Yaalon DH (ed) Paleopedology: origin, nature and dating of Paleosols. International Society of Soil Science and Israel Universities Press, Jerusalem, pp 153–158
Yaalon DH (1971b) Soil-forming processes in time and space. In: Yaalon DH (ed) Paleopedology: origin, nature and dating of Paleosols. International Society of Soil Science and Israel Universities Press, Jerusalem, pp 29–39